

3. SLIDE RULE ERRORS

The slide rule "instrumental" errors were found by computing winds and heights from four WF2 flights using the slide rule with painstaking care, keeping as many significant figures as the slide rule would permit, and checking the results with a digital computer. The computer program allowed for the approximation of 6000 ft to 1 nautical mile made in the slide rule computations, computed wind components and heights from the raw data, and printed out differences between its own computations and the observer's. All four flights used reached heights of 26 km or more.

The slide rule operational errors for wind were found in the same way, using 56 flights comprised of 1311 separate wind computations made by 31 separate observers working under the usual procedures. For height, 39 flights by 29 observers were treated in a similar manner.

4. DISCUSSION

Figures 1 to 4 show the results, for observations after the twelfth minute, made every second minute. The "instrumental" and "observational" errors shown in the figures are as defined in the Introduction. The "total" error is obtained by combining the variances of the instrumental and observational errors.

Ground range ($R \cos E$) was used as the abscissa in Figs. 1 and 2 because it was found that the errors are closely fitted by single curves. In the case of slide rule errors it can be shown that the vector wind error is proportional to $R \cos E$ (Spillane, 1968) for purely instrumental errors, i. e. not including "mistakes" in setting or in reading the slide rule, or in the associated mental arithmetic. Height errors for the slide rule can be treated in a similar manner and are found to be a function of height ($R \sin E$) only. The radar errors for height cannot be shown as a function of a single variable as can be done for wind vector, and a family of curves is needed (Figs. 3 and 4).

Although only 60 km range was the maximum reached in the flights used for determining observational radar errors, the curves of Figs. 1 to 4 have been extrapolated to greater ranges, the justification being that the observational errors were found to be substantially independent of range and elevation.

The instrumental radar and slide rule errors are compared and combined in Figures 1 and 3. In the flights studied the standard deviation of the wind vector error remains below 2 m sec^{-1} except at extreme ranges, i. e. even at 100 km ground range only 5 percent of winds will have errors greater than 4 m sec^{-1} . At moderate ranges (up to 60 km) the standard deviation remains below 1 m sec^{-1} . The slide rule makes only a relatively small contribution to the height error as only one slide rule operation is required to compute height. The height error due to radar increases with range, and arises mainly from elevation errors at great range. The standard deviation of about 140 m at 100 km range could be objectionable where there is a strong vertical shear.

In the routine use of the slide rule, about 10 percent of computed winds had large errors (more than 5 m sec^{-1}) which were identifiable as mistakes. The mean absolute value of the mistakes was 15 m sec^{-1} and their contribution to the overall standard deviation was about 5 m sec^{-1} , as shown in Fig. 2. If mistakes are excluded, the errors in routine slide rule computation compare favourably with the instrumental errors of Fig. 1. Mistakes in the computation of heights were very rare, as only one simple operation is required, and the observer can easily detect them during the flight.

It may be inferred that the large radar observational errors also include mistakes in reading the display dials and recording the readings.

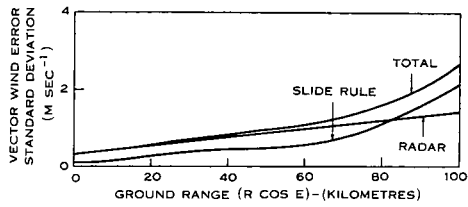


Fig. 1 Vector wind error due to instrumental error, for observations made every two minutes.

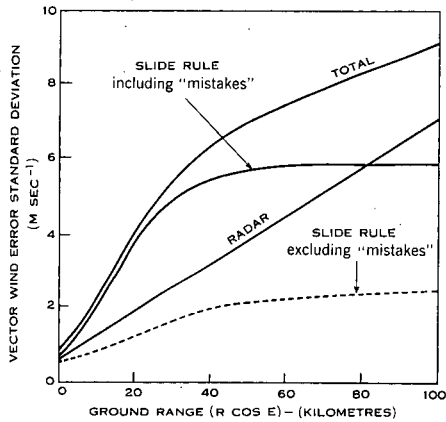


Fig. 2 Vector wind error due to instrumental plus observational errors, for observations made every two minutes.

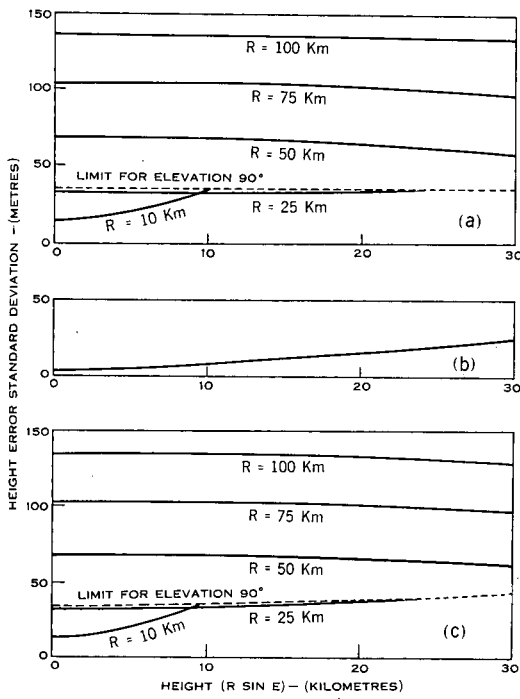


Fig. 3 Height error due to instrumental errors,
 (a) radar only
 (b) slide rule only
 (c) radar and slide rule combined.

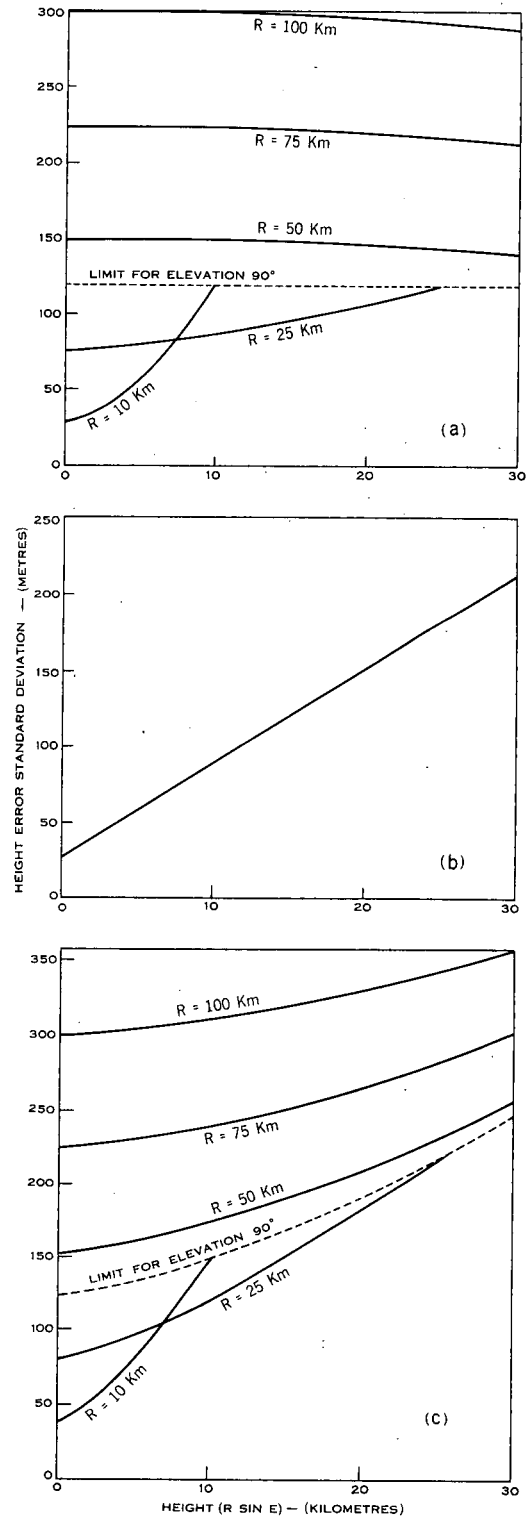


Fig. 4 Height error due to instrumental plus observational errors,
 (a) radar only
 (b) slide rule only
 (c) radar and slide rule combined.